ANSWERS FOR PROPERTIES OF MATTER

QUANTITIES FOR THE PROPERTIES OF MATTER UNIT

For this unit copy and complete the table.

Quantity	Symbol	Unit	Unit Symbol	Scalar / Vector
Pressure	P	Pascal	Pa	S
Force	F	Newton	N	V
Specific Heat Capacity	C	Joules per kilogram degrees Celsius	$Jkg^{-1}°C^{-1}$	S
Mass	m	Kilogram	Kg	S
Change in Temperature	ΔT	degrees Celsius or Kelvin	°C or K	S
Specific Latent Heat	l	Joules per kilogram	Jkg^{-1}	S
Volume	V	Cubic metres	m^3	S
Temperature	T	degrees Celsius or Kelvin	°C or K	S
Area	A	Square metres	m^2	S
Energy	E	Joule	J	S
Work done	E_W or W	Joule	J	S

THE PROPERTIES OF MATTER UNIT IN NUMBERS

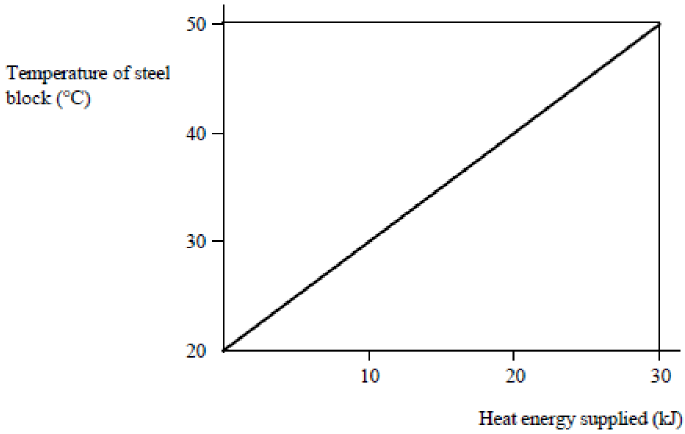
Quantity	Value
State the Specific Heat Capacity of Water.	4180 $Jkg^{-1}°C^{-1}$
State the specific Latent heat of fusion of ice.	$3{\cdot}34 \times 10^5$ Jkg^{-1}
State the specific latent heat of vaporisation of water.	$22{\cdot}6 \times 10^5$ Jkg^{-1}
State the average Atmospheric Pressure.	1×10^5 Pa
State the equivalent temperature of 0 °C in Kelvin.	273 K
State the temperature of 0 Kelvin in °C.	-273 °C
State the equivalent temperature of 100°C in Kelvin.	373 K
State the equivalent of 100 Kelvin in °C.	-173 °C
State the equivalent temperature change in kelvin of a one degree Celsius temperature change	1 K
State the conversion factor to change °C into Kelvin.	-273
State the conversion factor to change a temperature in Kelvin into °C	+273

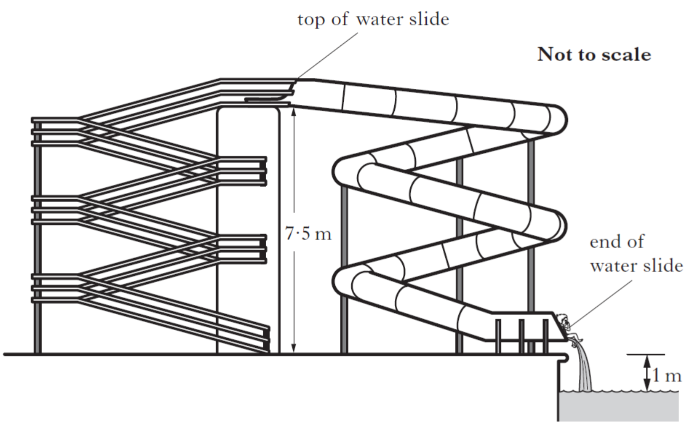
Quantity	Value
State the melting and boiling point of water.	Mpt 0 °CBpt 100 °C
State the melting and boiling point of alcohol.	*Melting point* -98°C *Boiling point* 65°C

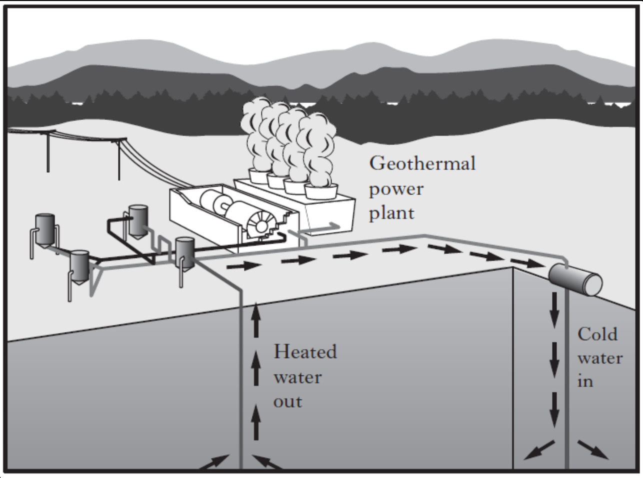
No.	CONTENT
Specific heat capacity	
14.1	**I know that the same mass of different materials require different quantities of heat energy to raise their temperature by 1 degree Celsius.**
14.1.1	Explain the term *Specific Heat Capacity*. The energy required to increase the temperature of 1kg of a substance by 1°C
14.1.2	When eating a cheese, pineapple, ham and tomato pizza the pineapple and tomato is much hotter when you bite into it than the ham, explain the reason for this. Hotter materials have a higher specific heat capacity and have taken more energy to heat but this is stored in the food and therefore takes longer to give out this energy. Most of the materials that remain hot have high volumes of water.
14.1.3	State the formula linking energy, mass, specific heat capacity, and change in temperature. State what each letter means. $E_h = mc\Delta T$ $E_h = energy\ (J)\ m = mass\ (kg), c = specific\ heat\ capacity\ Jkg^{-1}°C^{-1}$ $\Delta T\ change\ in\ Temperature\ °C^{-1}$,
14.1.4	Using the data sheet, state the specific heat capacity of (a) ice (b) copper (c) iron $2100\ Jkg^{-1}°C^{-1}$ $386\ Jkg^{-1}°C^{-1}$ $480\ Jkg^{-1}°C^{-1}$
14.1.5	From the list of materials given in the Data sheet, state the material that would take (a) most energy to heat up the material by 10 °C water 4180 $Jkg^{-1}°C^{-1}$ (b) least energy to heat up the material by 10 °C lead 128 $Jkg^{-1}°C^{-1}$
14.2	**I am able to use $E_h = cm\Delta T$ to carry out calculations involving: mass, heat energy, temperature change and specific heat capacity.**
14.2.1	Explain the difference between temperature and heat. Heat is a form of energy and temperature is an indication of how hot or cold something is and is a measure of the mean kinetic energy of the particles.

No.	CONTENT
14.2.2	10000 J of energy raises the temperature of 1 kg of liquid by 2 °C. Calculate the specific heat capacity of the material. $$E_h = mc\Delta T$$ $$10000 = 1 \times c \times 2$$ $$\frac{10000}{2} = c = 5000\ \text{Jkg}^{-1}{}^{\circ}\text{C}^{-1}$$
14.2.3	The specific heat capacity of concrete is about 800 Jkg^{-1}°C^{-1}. Calculate the heat stored in a storage heater containing 50 kg of concrete when it is heated through 100 °C. $$E_h = mc\Delta T$$ $$E_h = 50 \times 800 \times 100 = 4.0 \times 10^6 J$$
14.2.4	1.344 MJ of heat energy are used to heat from 20 °C to 100 °C. Calculate the mass of water. $$E_h = mc\Delta T$$ $$1.344 \times 10^6 = m \times 4180 \times (100 - 20)$$ $$\frac{1.344 \times 10^6}{4180 \times 80} = m = 4.0\ kg$$
14.2.5	9600 J of heat energy is supplied to 1 kg of methylated spirit in a polystyrene cup. Calculate the rise in temperature produced. Take the specific heat capacity of methylated spirit to be the same as alcohol. $$E_h = mc\Delta T$$ $$9600 = 1 \times 2350 \times \Delta T$$ $$\frac{9600}{2350} = \Delta T = 4.1\ ^{\circ}\text{C}$$
14.2.6	When 2.0 x 10^4 J of heat is supplied to 4.0 kg of paraffin at 10 °C in a container the temperature increases to 14 °C. a) Calculate the specific heat capacity of the paraffin. $$E_h = mc\Delta T$$ $$2.0 \times 10^4 = 4 \times c \times (14 - 10)$$ $$\frac{2.0 \times 10^4}{16} = \text{c} = 1250\ \text{Jkg}^{-1}{}^{\circ}\text{C}^{-1}$$ b) Explain why the result in part a) is different from the theoretical value of 2200 Jkg^{-1}°C^{-1}.**The paraffin could have absorbed energy from the air surrounding the container as it is lower than room temperature.** ***Suggesting that the paraffin container is being heated too would increase the measured value rather than decreasing it.***
14.2.7	Calculate the energy supplied to heat up 1.20 kg of water from 20.0°C to 100.0°C. Assume all the energy goes in to heating the water. $$E_h = mc\Delta T$$

No.	CONTENT
	$E_h = 1.20 \times 4180 \times (100 - 20) = 4.01 \times 10^5 J$
14.2.8	If 5000J of energy is used to heat up 0.80 kg of iron, (i) calculate the rise in temperature of the iron $E_h = mc\Delta T$ $5000 = 0.80 \times 480 \times \Delta T$ $\frac{5000}{384} = \Delta T = 13\ ℃$ (ii) If its initial temperature is 30°C, determine the final temperature of the iron. 43°C
14.2.9	A kettle is used to heat up water from 20°C to boiling point. It has a power of 2000W and takes 120 seconds to boil. (i) Calculate the energy supplied to the water. $E = Pt$ $E = 2000 \times 120 = 240000\,J$ (ii) If all of this energy is used to heat the water, determine the mass of water in the kettle. $E_h = mc\Delta T$ $240000 = m \times 4180 \times (100 - 20)$ $\frac{2.4 \times 10^5}{4180 \times 80} = m = 0.7\,kg$
14.2.10	If a kettle containing 2 kg of water cools from 40 °C to 25 °C, calculate the heat given out by the water. $E_h = mc\Delta T$ $E_h = 2 \times 4180 \times (40 - 25) = 125\,400\,J$
14.2.11	The temperature of a 0.8 kg metal block is raised from 27 °C to 77 °C when 4200 J of energy is supplied. Find the specific heat capacity of the metal. $E_h = mc\Delta T$ $4200 = 0.8 \times c \times (77 - 27)$ $\frac{4200}{50 \times 0.8} = c = 105\,Jkg^{-1}\,℃^{-1}$
14.2.12	The tip of the soldering iron is made of copper with a mass of 30 g. Calculate how much heat energy is required to heat up the tip of a soldering iron by 400 °C. Specific heat capacity for copper = 386 $Jkg^{-1}\,°C^{-1}$ $E_h = mc\Delta T$ $E_h = 30 \times 10^{-3} \times 386 \times 400 = 4600\,J$

No.	CONTENT
14.2.13	5.0 kg of a plastic is heated from 10°C to 66°C using 36000 J of energy. Calculate the specific heat capacity of the plastic. $E_h = mc\Delta T$ $36000 = 5.0 \times c \times (66 - 10)$ $\frac{36000}{5.0 \times 56} = c = 128\ Jkg^{-1}\,℃^{-1}$
14.2.14	The graph below represents how the temperature of a 2 kg steel block changes as heat energy is supplied. From the graph calculate the specific heat capacity of the steel.  Either work from the gradient or take figures from the graph $E_h = mc\Delta T$ $30 \times 10^3 = 2 \times c \times (50 - 20)$ $\frac{30 \times 10^3}{60} = c = 500\ \mathrm{Jkg^{-1}°C^{-1}}$ **OR** **The gradient of the graph is equal to** $gradient = \frac{change\ in\ temp}{E} = \frac{1}{mass \times specific\ heat\ capacity}$ $gradient = \frac{y_2 - y_1}{x_2 - x_1}$ • **Calculate the gradient** $m = \frac{50 - 20}{30 \times 10^3 - 0} = \frac{30}{30 \times 10^3} = 0.001$ $gradient = \frac{1}{mass \times specific\ heat\ capacity}$ $0.001 = \frac{1}{2.0 \times specific\ heat\ capacity}$ $c = \frac{1}{0.002} = 500\ \mathrm{Jkg^{-1}°C^{-1}}$
14.3	**I am able to explain how temperature of a substance is related to kinetic energy**
14.3.1	Explain how the temperature of a substance relates to the particle speed. **Temperature is a measure of the mean kinetic energy of the particles.**
14.3.2	(a) If the speed of the particles in a substance increases state what happens to the kinetic energy of the particles in the substance.

No.	CONTENT
	The kinetic energy of the particles will increase. (b) Hence, state the link between temperature of a substance and the kinetic energy of its particles. Temperature is a measure of the mean kinetic energy of the particles.
14.4	**I can use the principle of conservation of energy to determine heat transfer.**
14.4.1	A kettle works on the UK mains (230 V) and a current of 12.0 A flows when it is switched on. (a) Calculate the power rating of the kettle. $P = IV$ $P = 12.0 \times 230 = 2760\ W$ (b) Calculate the energy transformed by the kettle if it was switched on for 2 minutes. $E = Pt$ $E = 2760 \times 2 \times 60 = 3.3 \times 10^5\ J$ (c) Calculate the maximum mass of water at 20 °C which could be heated to 99 °C in this time. $E_h = mc\Delta T$ $3.3 \times 10^5 = m \times 4180 \times (99 - 20)$ $\frac{3.3 \times 10^5}{4180 \times (99 - 20)} = m = 1.0\ kg$ (d) State any assumptions you made in part c. All the energy heats the water and none of the heat warms the kettle, correct temperature change and none of the water evaporates.
14.4.2 Wrong unit Dynamics	 SQA SG C 2013 A child of mass 42.0 kg is playing on a water slide at a water park. (a) The child climbs 7·50 m to the top of the slide. Calculate the gain in potential energy of the child. $E_p = mgh$ $E_p = 42.0 \times 9.8 \times 7.50 = 3090\ J$ (c) When sliding down, an average frictional force of 15.0 N acts on the child. This causes 1050 J of heat energy to be produced. Calculate the length of the slide. $E = Fd$

No.	CONTENT
	$1050 = 15 \times d$ $\frac{1050}{15} = d = 70\ m$ (d) Calculate the speed of the child at the end of the slide. $E_k = E_p - E_w = 3090 - 1050 = 2040\ J$ $E_k = \frac{1}{2}mv^2 =$ $2040 = \frac{1}{2} \times 42 \times v^2$ $v = \sqrt{97.143} = 9.9\ ms^{-1}$
14.4.3	 SQA SG C 2013 An experimental geothermal power plant uses heat energy from deep underground to produce electrical energy. A pump forces water at high pressure down a pipe. The water is heated and returns to the surface. At this high pressure the boiling point of water is 180 °C. The plant is designed to pump 82.0 kg of heated water, to the surface, each second. The specific heat capacity of this water is 4320 J kg^{-1} °C^{-1}. (*a*) The water enters the ground at 20 °C and emerges at 145 °C. Calculate the heat energy absorbed by the water each second.

$E_h = cm\Delta T$	(½)	2	Must use value for c given in question, otherwise (½) mark max for equation
$= 4320 \times 82 \times 125$	(½)	(KU)	sig. fig. range 1–4
$= 44\ 280\ 000$ J	(1)		40 000 000 44 000 000 44 300 000 44 280 000

The hot water is fed into a heat exchanger where 60 % of this heat energy is used to vaporise another liquid into gas. This gas is used to drive a turbine which generates electrical energy. The specific latent heat of vaporisation for this liquid is 3·42 × 10^5 Jkg^{-1}.

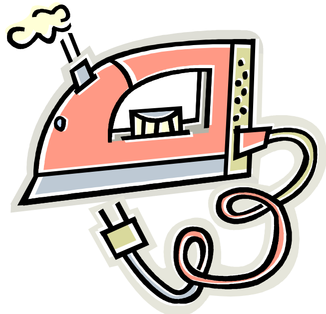
Calculate the mass of this liquid which is vaporised each second.

No.	CONTENT

60% × 44280000 = 26568000(J) (1) $E_h = ml$ (½) $26568000 = m \times 3{\cdot}42 \times 10^5$ (½) $m = 77{\cdot}7$ kg (1)	3 (PS)	or consistent with Q12(a) calculation of 60% may occur at any stage in the calculation. if no or wrong calculation using 60% is present , then award (½) mark max for latent heat equation sig. fig. range 2 - 5: 77·684, 77·68, 77·7, 78

14.4.4

SQA SG C 2012A



A manufacturer has developed an iron with an aluminium sole plate. A technician has been asked to test the iron. The technician obtains the following data for one setting of the iron.

Starting temperature of sole plate: 24°C

Operating temperature of the sole plate: 200°C

Time for iron to reach the operating temperature: 35 s

Power rating of the iron: 1·5 kW

Operating voltage: 230 V

Specific Heat Capacity of Aluminium: 902 $Jkg^{-1}°C^{-1}$

(a) Calculate how much electrical energy is supplied to the iron in this time.

$$E = Pt$$

$$E = 1.5 \times 10^3 \times 35 = 53000\,J$$

(b) Calculate the mass of the aluminium sole plate.

$$E_h = mc\Delta T$$

$$5.3 \times 10^4 = m \times 902 \times (200 - 24)$$

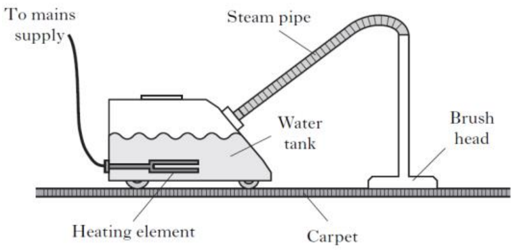
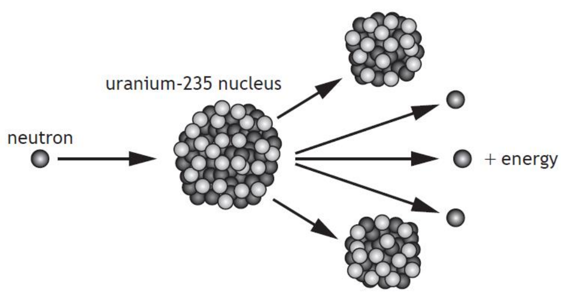
$$\frac{5.3 \times 10^4}{902 \times (200 - 24)} = m = 0.33\,kg$$

(c) The actual mass of the aluminium sole plate is less than the value calculated in part (b) using the technician's data. Give one reason for this difference.

Heat is
- Lost OR
- Radiated OR
- escapes OR

from the sole plate

Accept:
- Heat is lost/radiated/ escapes to the surroundings

No.	CONTENT
	▫ Some of the heat (energy) is used to heat other parts of the iron The explanation should indicate that heat is lost from/to... eg ▫ power rating of iron is incorrect ▫ inaccurate temperature readings etc.
14.4.5	A steam cleaner rated at 2.0 kW is used to clean a carpet. The water tank is filled with 1.60 kg of water at 20.0 °C. This water is heated until it boils and produces steam. The brush head is pushed across the surface of the carpet and steam is released.  (a) Calculate how much heat energy is needed to bring this water to its boiling point of 100 °C. $E_h = mc\Delta T$ $E_h = 1.60 \times 4180 \times (100 - 20) = 5.4 \times 10^5\ J$ (b) After the steam cleaner has been used for a period of time, 0.90 kg of boiling water has changed into steam. (i) Calculate how much heat energy was needed to do this. $E_h = ml_v$ $E_h = 0.90 \times 22 \cdot 6 \times 10^5 = 20 \cdot 3 \times 10^5\ J$ (ii) Calculate how long it would take to change this water into steam. $E = Pt$ $20 \cdot 3 \times 10^5 = 2.0 \times 10^3 \times t$ $\frac{20 \cdot 3 \times 10^5}{2.0 \times 10^3} = t = 1015\ s\ (16\ min\ 55\ s)$
14.4.6	SQA N5 2017 In a nuclear reaction a uranium-235 nucleus is split by a neutron to produce two smaller nuclei, three neutrons, and energy.  One nuclear reaction releases $3{\cdot}2 \times 10^{-11}$ J. In the reactor, $3{\cdot}0 \times 10^{21}$ reactions occur each minute. Determine the maximum power output of the reactor. $E = 3 \cdot 2 \times 10^{-11} \times 3.0 \times 10^{21}$

No.	CONTENT
	$$P = \frac{E}{t}$$ $$P = \frac{3.0 \times 10^{21}}{60} = 1.6 \times 10^{9}\ W$$ OR through Radiation Section $$A = \frac{No. of\ reactions}{time}$$ $$A = \frac{3.0 \times 10^{21}}{60} = 5.0 \times 10^{19}\ Bq$$ $$P = Energy\ per\ reaction\ \times Activity$$ $$P = 3.2 \times 10^{-11} \times 5.0 \times 10^{19} = 1.6 \times 10^{9}\ W$$
Specific Latent Heat	
15.1	**I know that different materials require different quantities of heat to change the state of unit mass.**
15.1.1	State what is meant by *change of state*. ***A change of state is when a substance changes between a solid and a liquid or a liquid and gas.***
15.1.2	Define the term *specific latent heat*. ***Specific latent heat is the ENERGY required to CHANGE THE STATE of1kg of a substance without a change in temperature.***
15.1.3	State what is meant by *latent heat of fusion*. **Specific latent heat is the ENERGY required to change 1kg of a solid to a liquid without a change in temperature.**
15.1.4	State what is meant by *latent heat of vaporisation*. **Specific latent heat is the ENERGY required to change 1kg of a liquid to a gas without a change in temperature**
15.1.5	Using the information in the data sheet, state the energy required to melt 1 kg of the following substances: a) ice **$3{\cdot}34 \times 10^{5}$ J** b) copper **$2{\cdot}05 \times 10^{5}$ J** c) aluminium **$3{\cdot}95 \times 10^{5}$ J**
15.2	**I know that the same material requires different quantities of heat to change the state of unit mass from solid to liquid (fusion) and to change the state of unit mass from liquid to gas (vaporisation)**
15.2.1	State which requires more energy, melting 1 kg of ice or boiling 1 kg of water. *You must justify your answer.* ***Boiling 1 kg of water takes more energy that melting 1 kg of ice. You can tell this as the latent heat of vaporisation of water is greater than the latent***

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heat of fusion of ice. Also the energy is required to completely separate the molecules (liquid to a gas) from each other is greater than that required to just alter the neat row spacing.

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<tr><td>15.2.2</td><td>

State whether 1 kg of water or 1 kg of molten copper will give out more energy as they change to a solid, you must justify your answer.

Changing 1 kg of water to ice will give out more energy than freezing 1 kg of molten copper as l_f Copper $=2{\cdot}05 \times 10^5$ Jkg^{-1}, l_f water $=3{\cdot}34 \times 10^5$ Jkg^{-1}. This is the same energy given required to change the state from solid to a liquid of copper and water.

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<tr><td>15.2.3</td><td>

State what happens to the temperature of a substance when it changes from a solid to a liquid.

Temperature remains constant.

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<tr><td>15.2.4</td><td>

Copy and complete this sentence:

When a substance changes state, its temperature ***remains constant***

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<tr><td>15.2.5</td><td>

State what you have to do to a material to make it turn from

(a) a liquid to a gas, and **add energy**

(b) from a liquid to a solid **remove energy**

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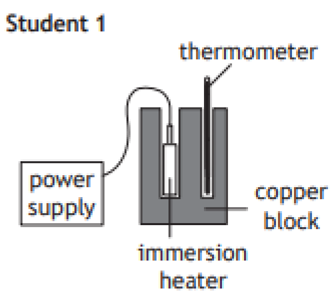
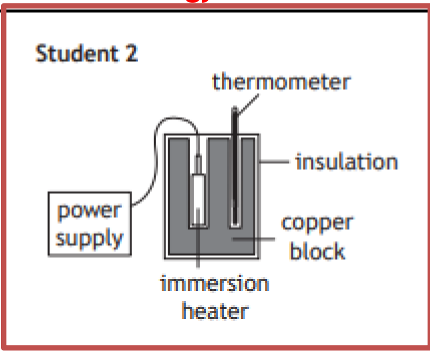
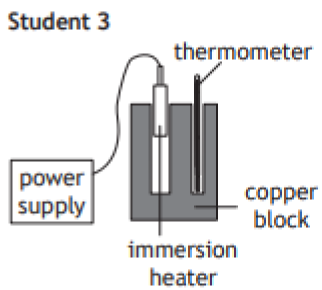
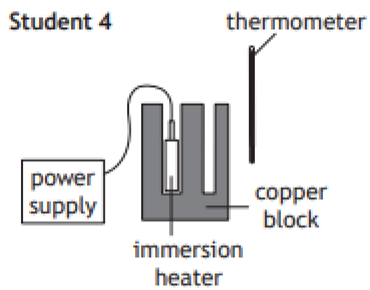
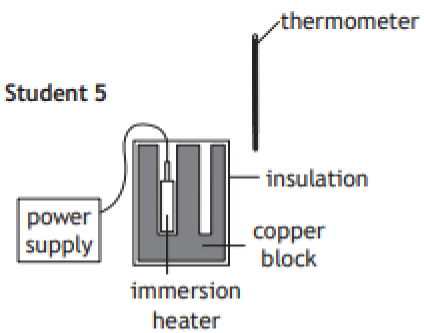




Draw the diagram of the student's setup that would allow the most accurate value for the specific heat capacity of copper to be determined.







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<tr><td>15.3</td><td>

I can solve problems involving mass, heat energy and specific latent heat.

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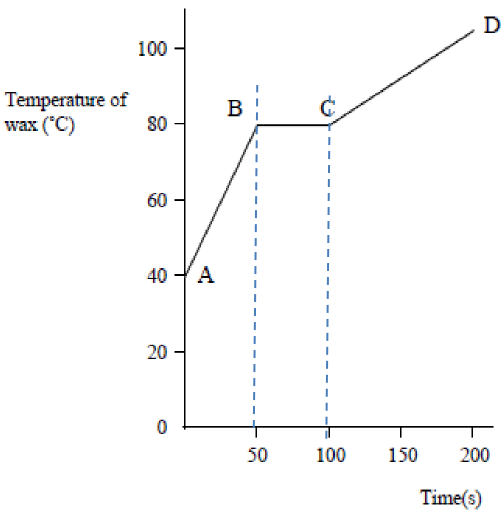
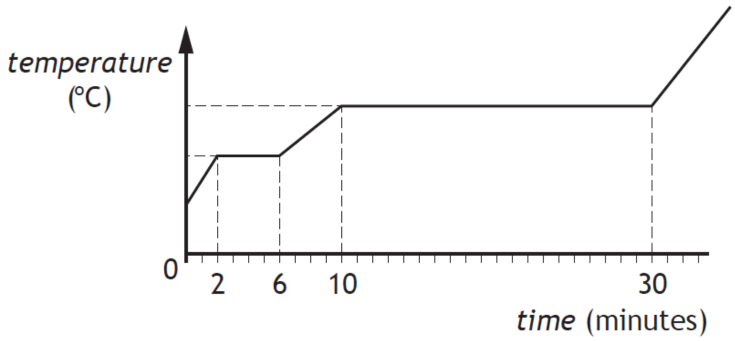
No.	CONTENT
15.3.1	State the formula linking mass energy and specific latent heat. State the units of each quantity. $$E_h = ml_f$$ $E_h = heat\ energy\ in\ Joules,\ m = mass\ in\ kg,\ l_f = specific\ latent\ heat\ in\ Jkg^{-1}$
15.3.2	Calculate the specific latent heat of fusion of naphthalene given that 6 x 10^5 J of heat is given out when 4.0 kg of naphthalene at its melting point changes to a solid. $$E_h = ml_f$$ $$6.0 \times 10^5 = 4 \times l_f$$ $$\frac{6.0 \times 10^5}{4} = l_f = 1.5 \times 10^5 Jkg^{-1}$$
15.3.3	Calculate the mass of water changed to steam if 10.6 kJ of heat energy is supplied to the water at 100 °C. From the data sheet lv water =22·6 × 10^5 J $$E_h = ml_v$$ $$10.6 \times 10^3 = m \times 22 \cdot 6 \times 10^5$$ $$\frac{10.6 \times 10^3}{22 \cdot 6 \times 10^5} = m = 0.0047\ kg^{-1}$$
15.3.4	Ammonia is vaporised in order to freeze an ice rink. a) Calculate the heat energy required to vaporise 1 g of ammonia. Specific latent heat of vaporisation of ammonia = 1.34 x 10^6 Jkg^{-1} $$E_h = ml_v$$ $$E_h = 1 \times 10^{-3} \times 1.34 \times 10^6 = 1.34 \times 10^3 \text{ J}$$ b) Assuming this heat is taken from water at 0 °C, find the mass of water frozen for every gram of ammonia vaporised. Specific latent heat of fusion of ice = 3.34 x 10^5 Jkg^{-1} $$E_h = ml_f$$ $$1.34 \times 10^3 = m \times 3.34 \times 10^5$$ $$\frac{1.34 \times 10^3}{3.34 \times 10^5} = m = 0.004\ kg$$ (Specific latent heat of vaporisation of ammonia = 1.34 x 10^6 Jkg^{-1} Specific latent heat of fusion of ice = 3.34 x 10^5 Jkg^{-1}).
15.3.5	(a) Explain how evaporation can be used to cool objects. **Alcohol wipes can be used to cool objects by evaporation. Alcohol has a lower boiling point than water. The energy to evaporate the alcohol comes from the objects around the wipe, thus cooling the object. (Think temperature probe and alcohol in cotton wool).** (b) Describe how melting can be used to keep things cool. **Cool boxes and ice**

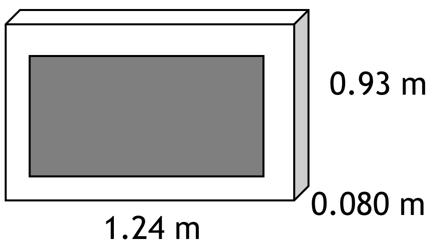
No.	CONTENT
	packs are used to keep things cool. The pack is put in the freezer until the chemicals have cooled and changed into a solid. The packs absorb the heat from the box and food and the chemicals in the pack change from a liquid from a solid keeping the food cool. The energy to melt the cool blocks comes from the food, thus keeping it cool.
15.3.6	Calculate the amount of heat energy required to melt 0.3 kg of ice at 0 ˚C. Specific latent heat of fusion of ice = 3.34 x 10^5 Jkg^{-1} $E_h = ml_f$ $E_h = 0.3 \times 3.34 \times 10^5$ $E_h = 1.0 \times 10^5 J$
15.3.7 Repeat	Calculate the specific latent heat of fusion of naphthalene given that 6 × 10^5 J of heat are given out when 4.0 kg of naphthalene at its melting point changes to a solid. $E_h = ml_f$ $6.0 \times 10^5 = 4 \times l_f$ $\frac{6.0 \times 10^5}{4} = l_f = 1.5 \times 10^5 Jkg^{-1}$
15.3.8 Repeat	Calculate what mass of water can be changed to steam if 10.6 kJ of heat energy is supplied to the water at 100 ˚C. From the data sheet lv water =22·6 × 10^5 J $E_h = ml_v$ $10.6 \times 10^3 = m \times 22 \cdot 6 \times 10^5$ $\frac{10.6 \times 10^3}{22 \cdot 6 \times 10^5} = m = 0.0047\ kg^{-1}$
15.3.9 Repeat	Ammonia is vaporised in order to freeze an ice rink. a) Find out how much heat it would take to vaporise 1.0 g of ammonia. b) Assuming this heat is taken from water at 0 ˚C, find the mass of water frozen for every gram of ammonia vaporised.(Specific latent heat of vaporisation of ammonia = 1.34 x 10^6 Jkg^{-1}) Ammonia is vaporised in order to freeze an ice rink. a) Calculate the heat energy required to vaporise 1 g of ammonia. Specific latent heat of vaporisation of ammonia = 1.34 x 10^6 Jkg^{-1} $E_h = ml_v$ $E_h = 1 \times 10^{-3} \times 1.34 \times 10^6 = 1.34 \times 10^3$ J b) Assuming this heat is taken from water at 0 ˚C, find the mass of water frozen for every gram of ammonia vaporised. Specific latent heat of fusion of ice = 3.34 x 10^5 Jkg^{-1} $E_h = ml_v$ $1.34 \times 10^3 = m \times 3.34 \times 10^5$

No.	CONTENT
	$$\frac{1.34 \times 10^3}{3.34 \times 10^5} = m = 0.004\ kg$$ (Specific latent heat of vaporisation of ammonia = 1.34 x 10^6 Jkg^{-1} Specific latent heat of fusion of ice = 3.34 x 10^5 Jkg^{-1}).
15.3.9	State what is meant by *Specific Heat Capacity* **The energy required (or given out) when 1 kg of a substance is heated by 1°C** State the formula linking Energy, mass, specific heat capacity, and change in temperature. State what each letter means. $$E_h = mc\Delta T$$ $$E_h = heat\ energy\ (J) \quad m = mass\ of\ material\ being\ heated\ (kg)$$ $$c = specific\ heat\ capacity\ (Jkg^{-1}\,℃^{-1})\ \Delta T = change\ in\ temperature\ (℃)$$
15.3.10	Calculate the energy required to melt 4.0 kg of ice. From the data sheet l_f =**3·34 × 10^5 Jkg^{-1}** $$E_h = ml_f$$ $$E_h = 4 \times 3 \cdot 34 \times 10^5$$ $$E_h = 13 \times 10^5\ J$$
15.3.11	Using the information in the data sheet, state the energy required to boil 1kg of the following substances: **This is the latent heat of vaporisation** a) water b) alcohol c) glycerol **22·6 × 10^5 J** **11·2 ×10^5 J** **8·30 × 10^5 J**
15.3.12	The graph below shows how the temperature of a 2.0 kg lump of solid wax varies with time when heated.  a) Explain what is happening to the wax in the regions AB, BC and CD. **AB heating the solid wax** **BC melting the wax** **CD heating the liquid wax** b) If a 200 W heater was used to heat the wax, calculate the specific latent heat of fusion of the solid wax. $$E = Pt$$ **From the graph the time to melt the wax is from 50-100 s = 50 s** $$E = Pt$$ $$E = 200 \times 50 = 10\ 000\ J$$ $$E_h = ml_f$$

No.	CONTENT
	$$10\ 000 = 2 \times l_f$$ $$\frac{10\ 000}{2} = l_f = 5\ 000\ Jkg^{-1}$$
15.3.13	A heater transfers energy to boiling water at the rate of 1130 joules every second. Calculate the maximum mass of water converted to steam in 2 minutes. $$E = Pt$$ $$E = 1130 \times 120 = 135\ 600\ J$$ $$E_h = ml_v$$ $$135\ 600 = m \times 22.6 \times 10^5$$ $$\frac{135\ 600}{22.6 \times 10^5} = m = 0.06\ kg$$
15.3.14	A kettle is rated at 230 V 10 A. (a) Calculate the power rating of the kettle. $$P = IV$$ $$P = 10 \times 230 = 2300\ W$$ (b) Calculate the time it will take to heat 1.3 kg of water from 10 °C to boiling point using the kettle, *assume all the energy goes into the water*. $$E_h = mc\Delta T$$ $$E_h = 1.3 \times 4180 \times (100 - 10) = 489060\ J$$ $$E = Pt$$ $$489060 = 2300 \times t$$ $$\frac{489060}{2300} = t = 210\ s$$ (c) The kettle in part (a) is faulty and does not switch its self off when it boils. If it boils the water for 5 minutes before it is noticed, determine the mass of water turned into steam. $$E = Pt$$ $$E = 2300 \times (5 \times 60) = 6.9 \times 10^5\ J$$ $$E_h = ml_v$$ $$6.9 \times 10^5 = m \times 22.6 \times 10^5$$ $$\frac{6.9 \times 10^5}{22.6 \times 10^5} = m = 0.3\ kg$$
15.3.15	(i) From the data sheet, state the melting point of aluminium.

No.	CONTENT
	Aluminium melts at 660 °C (ii) Calculate the energy needed to melt 5 kg of aluminium at its melting point. $$\textit{From the Data Sheet Aluminium } 3\cdot 95\times 10^{5}\,Jkg^{-1}$$ $$E_h = ml_f$$ $$E_h = 5\times 3.95\times 10^{5} = 2\times 10^{6}\,J$$
15.3.16	A solid substance vis placed in an insulated flask and heated continuously with an immersion heater. The graph shows how the temperature of the substance in the flask changes in time.  State in which state(s) the substance is after being heated for 5 minutes. **After being heated for 5 mins the graph shows a flat gradient, i.e. the temperature isn't changing. This is the lower of the two flat gradients so the flask must have a mixture of ice and water. After 5 mins most of the ice would have changed to water. So in the flask there will be some <u>solid</u> and some <u>liquid.</u>**

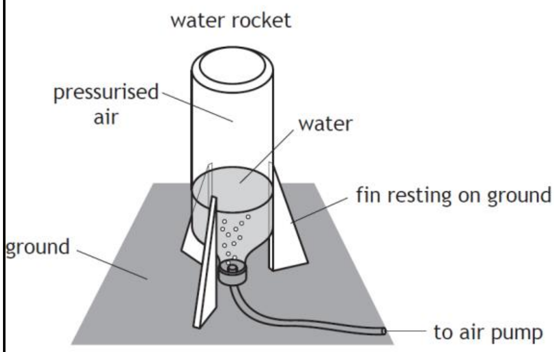
Gas laws and the kinetic model

No.	CONTENT
16.1	**I can explain pressure**
16.1.1	State the meaning of the term pressure. **Pressure if the force per unit area and it is measured in Pascals**
16.1.2	State the equation linking force and pressure, define each term. $$p = \frac{F}{A}$$ **p=pressure (Pa), F= Force (N), A = area (m^{-2})**
16.2	**I am able to use the correct equation to calculate pressure, force and area**
16.2.1	A television has a length of 1.24 m, a height of 0.93 m and a depth of 0.080 m. If it has a mass of 30 kg.  (a) Calculate the maximum pressure that the television can exert on a surface. **The maximum pressure will arise when the area is at its smallest, so this is**

No.	CONTENT
	when it is leaning on its smallest two sides $$A = l \times b$$ $$A = 0.080 \times 0.93 = 0.0744\ m^2$$ (b) Calculate the minimum pressure that the television can exert on a surface. The force is the weight of the TV $$W = m \times g$$ $$W = 30 \times 9.8 = 294\ N$$ $$p = \frac{F}{A}$$ $$p = \frac{294}{0.0744} = 4.0 \times 10^3\ Pa$$
16.2.2	The mass of a spacecraft is 1200 kg. The spacecraft lands on the surface of a planet. The gravitational field strength on the surface of the planet is 5·0 N kg^{-1}. The spacecraft rests on three pads. The total area of the three pads is 1·5 m^2. Determine the pressure exerted by these pads on the surface of the planet. The force is the weight of the spacecraft $$W = m \times g$$ $$W = 1200 \times 5.0 = 6\,000\ N$$ $$p = \frac{F}{A}$$ $$p = \frac{6000}{1.5} = 4.0 \times 10^3\ Pa$$
16.2.3	The pressure of the air outside an aircraft is 0·40 × 10^5 Pa. The air pressure inside the aircraft cabin is 1·0 × 10^5 Pa. The area of an external cabin door is 2·0 m^2. Calculate the outward force on the door due to the pressure difference. $$p = \frac{F}{A}$$ $$(1 \cdot 0 \times 10^5 - 0 \cdot 4 \times 10^5) = \frac{F}{2.0}$$ $$F = 1 \cdot 2 \times 10^5\ N$$
16.2.4	A 0.480 kg tin of baked beans is a cylinder with a radius of 0.032 m. It is placed on a kitchen counter. Calculate the pressure on the counter caused by the tin. Area of a cylinder = πr^2

No.	CONTENT
	$$p = \frac{F}{A}$$ $$p = \frac{(0.480 \times 9.8)}{\pi \times 0.032^2} = 1500\ Pa$$
16.2.5	A car of mass 1250 kg is driven on to a bridge. The pressure on the surface of the bridge when all four tyres are on the ground is 39.0 kPa. Calculate the contact area of one tyre on the bridge. $$p = \frac{F}{A}$$ $$39.0 \times 10^3 = \frac{(1250 \times 9.8)}{A}$$ $$A = \frac{(1250 \times 9.8)}{39.0 \times 10^3} = 0.314\ m^2$$ $$Area\ of\ 1\ tyre = \frac{0.314}{4} = 0.0785\ m^2$$
16.2.6	By measuring your weight and the area of your feet, calculate the pressure that you exert on the floor when: (a) You are standing normally. (this would cover most people) Your mass could be somewhere between 30-150 kg so your weight will be 9.8 times this. The length of your feet could be anywhere between 0.10 m and 0.40 m, with a width of 0.05-0.10 m, So going through extremes, largest person with smallest feet and smallest person with largest feet lets try some calculations. **Let's go for a large person with small feet (x2 as you've 2 feet)** $$W = m \times g$$ $$W = 150 \times 9.8 = 1470\ N$$ $$p = \frac{F}{A}$$ $$p = \frac{1470}{(0.10 \times 0.05 \times 2)} = 2 \times 10^5\ Pa$$ **Let's try a small person with large feet (x2 as you've 2 feet)** $$W = m \times g$$ $$W = 30 \times 9.8 = 294\ N$$ $$p = \frac{F}{A}$$

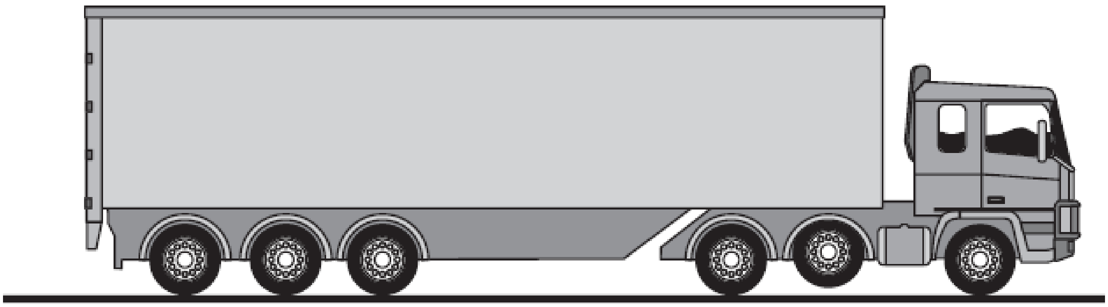
No.	CONTENT
	$$p = \frac{294}{(0.10 \times 0.40 \times 2)} = 4 \times 10^3\ Pa$$ I'd say most of you should have a pressure on the ground between 4 kPa and 200 kPa. Notice, I only give the answer to 1 sig fig as these are estimates. (b) You are standing on one foot. **Let's go for a large person with small feet** $$W = m \times g$$ $$W = 150 \times 9.8 = 1470\ N$$ $$p = \frac{F}{A}$$ $$p = \frac{1470}{(0.10 \times 0.05)} = 3 \times 10^5\ Pa$$ **So you can see if you are standing on one foot (and assuming both feet are about the same size) your pressure on the ground doubles**
16.2.7	Are you more likely to fall through an icy lake if you are on your tip toes or lying flat on your back with your arms and legs stretched out? Explain your answer. **Using the figures in the question above, you want a large area to reduce the pressure and then you will be less likely to fall through the ice. So if you want to fall through the ice creep out on tip toe.** **Let's go for a small person with small feet (tip toe will be about the same as going on one foot as above)** $$W = m \times g$$ $$W = 50 \times 9.8 = 490\ N$$ $$p = \frac{F}{A}$$ $$One\ foot\ p = \frac{490}{(0.10 \times 0.05)} = 1 \times 10^4\ Pa$$ $$body\ \ p = \frac{490}{(1.5 \times 0.4)} = 800\ Pa$$
16.2.8	SQA N5 2014 A student is investigating the motion of water rockets. The water rocket is made from an upturned plastic bottle containing some water. Air is pumped into the bottle. When the pressure of the air is great enough the plastic bottle is launched upwards.

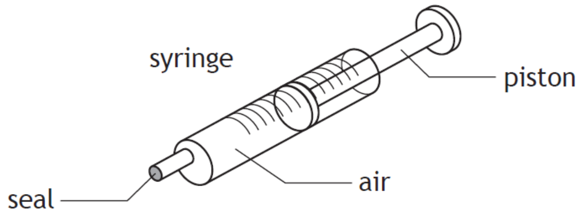
No.	CONTENT
	 The mass of the rocket before launch is 0·94 kg. a) Calculate the weight of the water rocket.

Answer		Max Mark
$W = mg$	(1)	3
$= 0\cdot94 \times 9\cdot8$	(1)	
$= 9\cdot2$ N	(1)	

b) Before launch, the water rocket rests on three fins on the ground. The area of each fin in contact with the ground is $2\cdot0 \times 10^{-4}$ m^2. Calculate the total pressure exerted on the ground by the fins.

Method 1		4	or consistent with (a)
$A = 3\times\left(2\cdot0\times10^{-4}\right)$ $= 6\cdot0\times10^{-4}$ (m^2)	(1)		Each method requires to multiply or divide by 3. This can appear at any stage in the candidate response, but if this does not appear then MAX (3) marks.
$p = \dfrac{F}{A}$	(1)		
$= \dfrac{9\cdot2}{6\cdot0\times10^{-4}}$	(1)		s.f. range: 1-4 if 9·2 used, 20 000, 15 000, 15 300, 15 330
$= 1\cdot5\times10^{4}$ Pa	(1)		s.f. range: 1-4 if 9·21 used, 20 000, 15 000, 15 400, 15 350
			s.f. range: 1-4 if 9·212 used, 20 000, 15 000, 15 400, 15 350

No.	CONTENT
	Method 2 $p = \frac{F}{A}$ (1) $= \frac{9 \cdot 2}{2 \cdot 0 \times 10^{-4}}$ (1) $= 4 \cdot 6 \times 10^{4}$ (Pa) (1) (If this line is the candidate's final answer, unit required.) total $p = \frac{4 \cdot 6 \times 10^{4}}{3}$ $= 1 \cdot 5 \times 10^{4}$ Pa (1) **Method 3...** Alternative - take 1/3 of weight and use this for *F* in *p* = *F*/*A*
16.2.9 **OEQ**	An articulated lorry has six pairs of wheels. One pair of wheels can be raised off the ground.  **Using your knowledge of physics**, comment on situations in which the wheels may be raised or lowered. **Limited PHYSICS knowledge (1), Reasonable (2), Good (3)** **You could talk about Force, weight, Pressure = Force/Area. The more wheels on the ground the greater the area so the lower the pressure. As weight increases (loading the lorry) the pressure on the ground increases, so spread this with greater area to reduce the pressure.** **You could show this with a made up calculation showing the A increasing from 10 to 12 "wheels"**

<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td></td><td>Why would the wheels be lifted, reduce wear from friction on tyres, and potential friction reducing fuel consumption.</td></tr>
<tr><td>16.3</td><td>I can describe the kinetic model of a gas.</td></tr>
<tr><td>16.3.1</td><td>A syringe containing air is sealed at one end as shown.
The piston is pushed in slowly.
There is no change in temperature of the air inside the syringe.


Copy the statement which describes and explains the change in pressure of the air in the syringe.

A The pressure increases because the air particles have more kinetic energy.
B The pressure increases because the air particles hit the sides of the syringe more frequently.
C The pressure increases because the air particles hit the sides of the syringe less frequently.
D The pressure decreases because the air particles hit the sides of the syringe with less force.
E The pressure decreases because the air particles have less kinetic energy.</td></tr>
<tr><td>16.3.2</td><td>State the properties of an ideal gas.
An ideal gas has a number of properties; real gases often exhibit behaviour very close to ideal. The properties of an ideal gas are:

• An ideal gas consists of a large number of identical molecules.
• The volume occupied by the molecules themselves is negligible compared to the volume occupied by the gas.
• The molecules obey Newton's laws of motion, and they move in random motion.
• The molecules experience forces only during collisions; any collisions are completely elastic, and take a negligible amount of time.</td></tr>
<tr><td>16.3.3</td><td>Explain the kinetic theory of an ideal gas.

For gases, the kinetic theory model explains that gas pressure is caused by the collisions between the particles and their container. This is called the outward pressure and is usually greater than normal atmospheric pressure outside the container.

KINETIC THEORY

All particles are moving.

Pressure is caused when the particles collide with the container walls

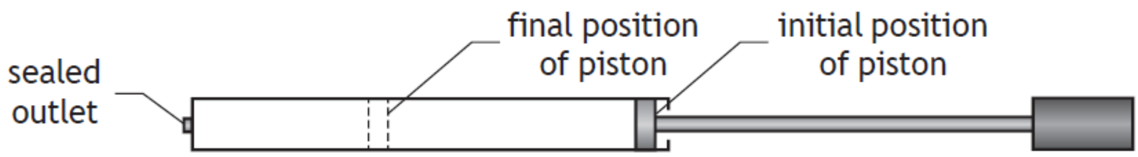
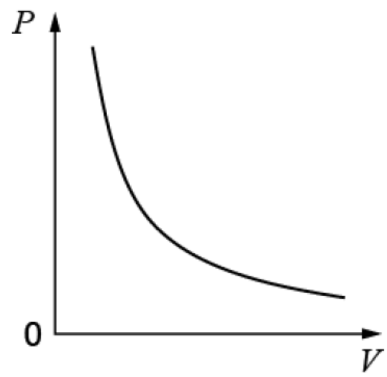
The higher the temperature of the particles the higher their average speed.

The greater their average speed the more often and more violent the collisions with the walls, greater impulse therefore greater force.

If the volume is less they will collide more often as there is a shorter distance between the container walls</td></tr>
</table>

No.	CONTENT
16.4	**I can describe the kinetic model of a gas and how this accounts for pressure**
16.4.1	Explain the term pressure. **Pressure if the force per unit area. It is measured in Pa.**
16.4.2	Explain how the kinetic model of a gas accounts for pressure. **Pressure is caused when the particles collide with the container walls**
16.4.3	Explain what happens to the particles of a gas as the temperature of the gas increases. **The higher the temperature of the particles the higher their average speed.** **The greater their average speed the more often and more violent the collisions with the walls, greater impulse therefore greater force.**
16.5	**I can convert temperatures between kelvin and degrees Celsius and understand the term absolute zero of temperature.**
16.5.1	Convert the following temperatures into kelvin a) 0 °C, b) 20 °C, c) -273 °C , d)100 °C **Add 273 to convert degrees Celsius to Kelvin** **a) 273 K b) 293 K c) 0 K d) 293 K**
16.5.2	Convert the following temperatures into degrees Celsius a) 0 K, b) 20 K, c) 273 K d) 100 K, e) 500 K **Subtract 273 to convert from Kelvin to degrees Celsius** b) **-273 °C b) -253 °C c) -173 °C d) 227 °C**
16.5.3	The average temperature of the surface of the Sun is 5778 K. Determine the average temperature of the surface of the Sun in degrees Celsius. **Subtract 273 to convert from Kelvin to degrees Celsius** **5500 °C**
16.5.4	A liquid is heated from 17 °C to 50 °C. Determine the temperature rise in kelvin. A temperature change in degrees Celsius is the same as a temperature change in Kelvin $\Delta T = T_1 - T_2$ $\Delta T = 50 - 17 = 33\ K$
16.5.5	A solid at a temperature of −20 °C is heated until it becomes a liquid at 70 °C. Calculate the temperature change in kelvin. A temperature change in degrees Celsius is the same as a temperature change in Kelvin $\Delta T = T_1 - T_2$ $\Delta T = 70 - -20 = 90\ K$

No.	CONTENT
16.5.6	State the freezing and boiling points of water at standard pressure on the degree Celsius scale and kelvin scale <table><tr><td></td><td colspan="2">Temperature</td></tr><tr><td></td><td>degrees Celsius</td><td>Kelvin</td></tr><tr><td>Freezing /melting point</td><td>0</td><td>273</td></tr><tr><td>Boiling point</td><td>100</td><td>373</td></tr></table>
16.6	**I know the link between kelvin and the degrees Celsius °C scale**
16.6.1	State the link between Kelvin and the degree Celsius scale. **ΔT (K) = ΔT (°C) 0 K = -273 °C**
16.6.2	Copy and complete this sentence A change of temperature of 1°C is equal to a change of temperature of **1 K**
16.6.3	Copy and complete this sentence To convert between kelvin and degrees Celsius **subtract 273** To convert between degrees Celsius and kelvin **add 273**
16.6.4	Explain in terms of moving particles what occurs at a temperature of zero kelvin. **At zero Kelvin the particles have no kinetic energy as the particles are not moving.**
16.7	**I can explain the relationship between the volume, pressure and temperature of a fixed mass of gas using qualitative (info) in terms of kinetic theory.**
16.7.1	Explain how the kinetic theory suggests that as the temperature of a fixed mass of gas increases the pressure increases. **If the volume of the container remains constant as the temperature of a sealed container of gas is increased, the kinetic energy and hence velocity of the gas molecules increases. The gas molecules therefore hit the walls of the container more frequently and more violently - so the force on the walls is greater. As p=F/A, pressure increases.**
16.7.2	Explain how the kinetic theory suggests that as the temperature of a fixed mass of gas increases the volume increases for constant pressure. **According to Kinetic Theory, an increase in temperature will increase the average kinetic energy of the molecules. As the particles move faster, they will likely hit the walls of the container more often. If the reaction is kept at constant pressure, they must stay farther apart, and an increase in volume will compensate for the increase in particle collision with the surface of the container. Remember p = F/A, Pressure is caused by the force of the particles on the walls of the container.**
16.7.3	Explain how the kinetic theory suggests that as the volume of a fixed mass of gas increases the pressure decreases.

No.	CONTENT
	As the volume of the container increases the particles collide with container walls and with each other less often. This causes a decrease of the force exerted on the container walls. As the overall force decreases this results in a decrease in pressure since P = F/A,
16.7.4	When completing an experiment to find the relationship between volume and pressure, explain why it is important to change the volume slowly. **If the volume is changed rapidly this will increase the speed of the particles and will therefore increase the temperature of the gas.**
16.7.5 A	SQA N5 2017 A bicycle pump with a sealed outlet contains $4{\cdot}0 \times 10^{-4}$ m^3 of air. The air inside the pump is at an initial pressure of $1{\cdot}0 \times 10^5$ Pa. The piston of the pump is now pushed slowly inwards until the volume of air in the pump is $1{\cdot}6 \times 10^{-4}$ m^3 as shown.  Using the kinetic model, explain what happens to the pressure of the air inside the pump as its volume decreases. **(individual) particles collide with container/walls more frequently (than before) (1) (overall) force (on walls) is greater (1) pressure increases (1)**
16.7.5 B	(continued from above) The piston is now released, allowing it to move outwards towards its original position. During this time the temperature of the air in the pump remains constant. Sketch a graph to show how the pressure of the air in the pump varies as its volume increases. *Numerical values are not required on either axis.* axes labelled p and V (1) correct shape (curved) (1) 
16.8	**I can use appropriate relationships to calculate the volume, pressure and temperature of a fixed mass of gas** $p_1V_1/T_1(K)= p_2V_2/T_2(K)$. $p_1V_1 = p_2V_2$ $p_1/T_1(K) = p_2/T_2(K)$ $V_1/T_1(K) = V_2/T_2(K)$ $pV/T(K)=$ *constant*
16.8.1	The pressure of a fixed mass of gas is 150 kPa at a temperature of 27 °C. The temperature of the gas is now increased to 47 °C.

No.	CONTENT
	The volume of the gas remains constant. Determine the new pressure of the gas. **Remember in all of these questions the temperature must be converted to Kelvin or the relationship is not proportional.** **Convert 27** °C to K = 300 K **Convert 47** °C to K = 320 K $\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}$. $\frac{150 \times 10^3}{300} = \frac{p_2}{320}$ $p_2 = \frac{150 \times 10^3 \times 320}{300} = 160 \times 10^3 Pa$
16.8.2	The pressure of a fixed mass of gas is 6·0 x 10^5 Pa. The temperature of the gas is 27 °C and the volume of the gas is 2·5 m^3. The temperature of the gas increases to 54 °C and the volume of the gas increases to 5·0 m^3. Determine the new pressure of the gas. **Remember in all of these questions the temperature must be converted to Kelvin or the relationship is not proportional.** **Convert 27 °C to K = 300 K** **Convert 54 °C to K = 327 K** $\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}$. $\frac{600 \times 10^3 \times 2.5}{300} = \frac{p_2 \times 5.0}{327}$ $p_2 = \frac{600 \times 10^3 \times 2.5 \times 327}{300 \times 5.0}$ $p_2 = 3.27 \times 10^5 Pa$
16.8.3	A mass of gas at a pressure of 20 kPa has a volume of 3.0 m^3. Calculate the new volume if the pressure is doubled but the temperature remains constant. $\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}$. $\frac{20 \times 10^3 \times 3.0}{\cancel{T_1(K)}} = \frac{40 \times 10^3 \times V_2}{\cancel{T_1(K)}}$ $V_2 = \frac{20 \times 10^3 \times 3.0}{40 \times 10^3}$ $V_2 = 1.5\, m^3$

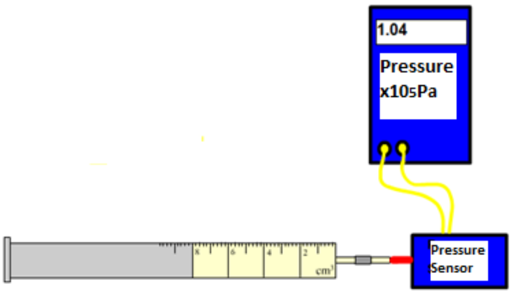
No.	CONTENT
16.8.4	The volume of mass of a gas is reduced from 5.0 m^3 to 2.0 m^3. If the pressure was initially 40 Pa, calculate be the new pressure if the temperature remains constant. $$\frac{p_1V_1}{T_1(K)}=\frac{p_2V_2}{T_2(K)}.$$ $$\frac{40\times10^3\times5.0}{\cancel{T_1(K)}}=\frac{v\times2.0}{\cancel{T_2(K)}}$$ $$p_2=\frac{40\times10^3\times5.0}{2.0}$$ $$p_2=100\times10^3\ Pa$$
16.8.5	The pressure of a fixed volume of gas at 300 K is increased from 5.0 Pa to 10.0 Pa, calculate the new temperature. $$\frac{p_1V_1}{T_1(K)}=\frac{p_2V_2}{T_2(K)}.$$ $$\frac{5.0\times\cancel{V_1}}{300}=\frac{10.0\times\cancel{V_2}}{T_2(K)}$$ **If what you want is on the bottom the easiest way to calculate the answer.** $$\frac{300}{5.0}=\frac{T_2}{10.0}$$ $$T_2=600\ K$$
16.8.6	If pressure of a fixed volume of gas at 200 K is 50.0 Pa, calculate the pressure if the temperature is increased to 300 K? $$\frac{p_1V_1}{T_1(K)}=\frac{p_2V_2}{T_2(K)}.$$ $$\frac{50\times\cancel{V}}{200}=\frac{p_2\times\cancel{V}}{300}$$ $$p_2=\frac{50\times300}{200}$$ $$p_2=75\ Pa$$
16.8.7	The temperature of 6.0 m^3 of gas is increased from 27 °C to 127 °C, calculate the new volume of the gas if the pressure remains constant.

No.	CONTENT
	Remember to change the temperature to Kelvin 27 °C =27 +273 = 300 K 127 °C =127 +273 = 400 K $$\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}.$$ $$\frac{\cancel{p_1} \times 6.0}{300} = \frac{\cancel{p_2} \times V_2}{400}$$ $$V_2 = \frac{400 \times 6.0}{300}$$ $$V_2 = 8.0\ m^3$$
16.8.8	The volume of a gas is increased from 10.0 m^3 to 20.0 m^3 at constant pressure. Calculate the new temperature if the initial temperature was 300 K. $$\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}.$$ $$\frac{\cancel{p_1} \times 10.0}{300} = \frac{\cancel{p_2} \times 20.0}{T_2(K)}$$ If what you want is on the bottom the easiest way to calculate the answer. $$\frac{300}{10.0} = \frac{T_2}{20.0}$$ $$T_2 = 600\ K$$
16.8.9	A mass of gas has a volume of 5.0 m^3, a pressure of 20.0 Pa and a temperature of 27 °C. Calculate the new pressure if the volume is changed to 4.0 m^3 and the temperature to 27 °C. Calculate the new pressure if the volume is changed to 4.0 m^3 and the temperature to 127 °C. (there was an error in the original, so I'll do the calculation twice.) For T remaining at 27 °C $$\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}.$$ $$\frac{20.0 \times 5.0}{\cancel{T_1(K)}} = \frac{p_2 \times 4.0}{\cancel{T_1(K)}}$$

No.	CONTENT
	$$p_2 = \frac{20.0 \times 5.0}{4.0}$$ $$p_2 = 25.0\ Pa$$ Now for all three quantities changing 27 °C =27 +273 = 300 K 127 °C =127 +273 = 400 K $$\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}.$$ $$\frac{20.0 \times 5.0}{300} = \frac{p_2 \times 4.0}{400}$$ $$p_2 = \frac{20.0 \times 5.0 \times 400}{300 \times 4.0}$$ $$p_2 = 33\ Pa$$
16.8.10	A sealed bicycle pump contains 4·0 × 10^{-5} m^3 of air at a pressure of 1·2 × 10^5 Pa. The piston of the pump is pushed in until the volume of air in the pump is reduced to 0·80 × 10^{-5} m^3. During this time the temperature of the air in the pump remains constant. Calculate the new pressure of the air in the pump. $$\frac{p_1V_1}{T_1(K)} = \frac{p_2V_2}{T_2(K)}.$$ $$\frac{1.2 \times 10^5 \times 4.0 \times 10^{-5}}{\cancel{T_1(K)}} = \frac{p_2 \times \cancel{V}}{\cancel{T_1(K)}}$$ $$p_2 = \frac{1.2 \times 10^5 \times 4.0 \times 10^{-5}}{0.8 \times 10^{-5}}$$ $$p_2 = 6.0 \times 10^5\ Pa$$
16.9	**I can describe an experiment to verify Boyle's Law (pressure and volume)**

No.	CONTENT

16.9.1

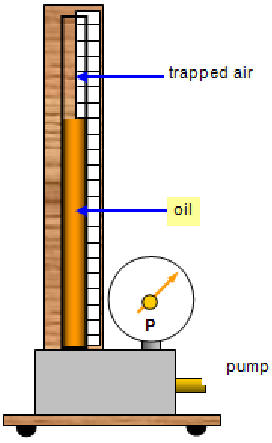


Explain how the following equipment can be used to show the relationship between pressure and volume. State the measurements required and how the variable will be altered. Include any assumptions made.

The gas is trapped in the syringe. The volume of the air is altered by pushing in the plunger. The pressure is read from the digital pressure gauge.

This assumes the plunger is pushed gently to avoid a change in temperature and the air in the tube is insignificant and included in the overall volume of the gas.

16.9.2



Explain how the equipment is different from that in 16.9.2 in collecting data to find the relationship between pressure and volume.

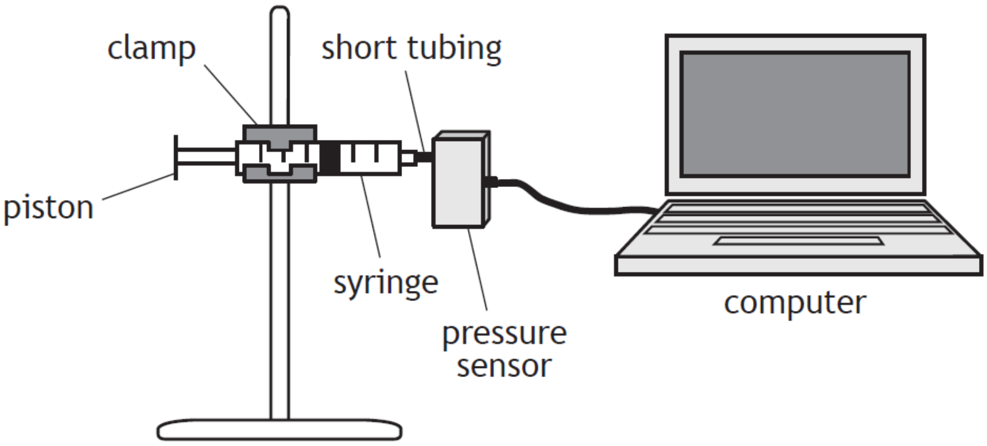
The gas is trapped in the closed tube. The volume of the air is altered by using the pump, which measures the pressure. The pressure is read from the bourdon gauge.

Oil is used to trap the air in the tube.

As above the pressure should be changed slowly to avoid a change in temperature.

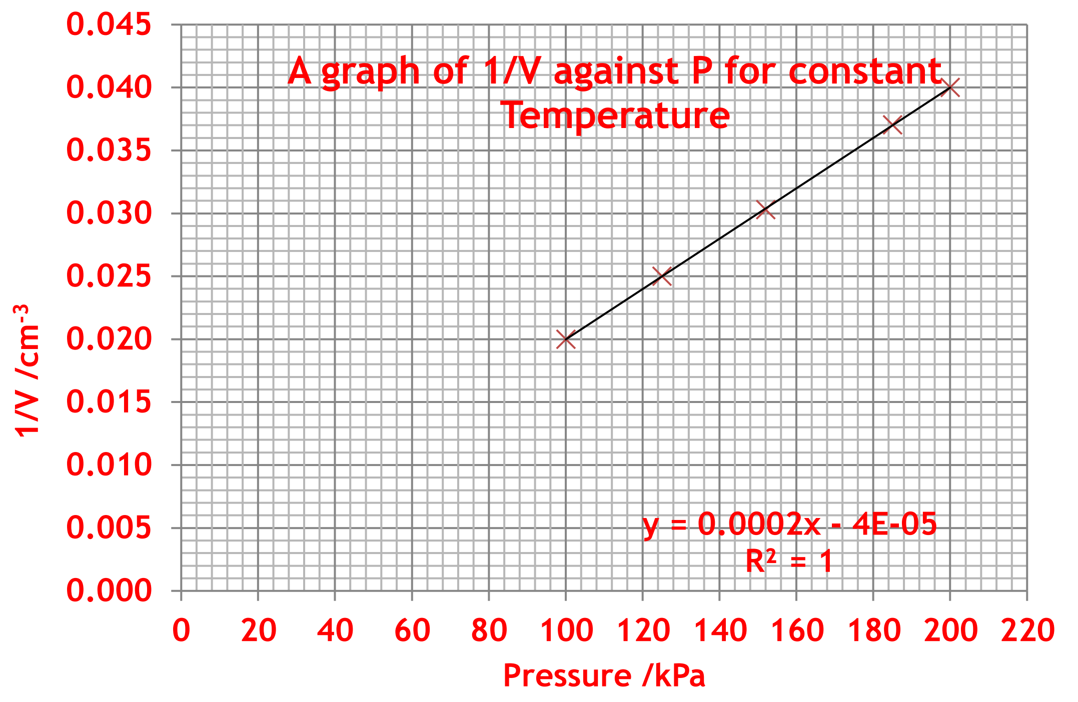
16.9.3

SQA N5 2017 SP
A student carries out an experiment to investigate the relationship between the pressure and volume of a fixed mass of gas using the apparatus shown.



The pressure p of the gas is recorded using a pressure sensor connected to a computer. The volume V of the gas in the syringe is also recorded. The student pushes the piston to alter the volume and a series of readings is taken.
The temperature of the gas is constant during the experiment.
The results are shown.

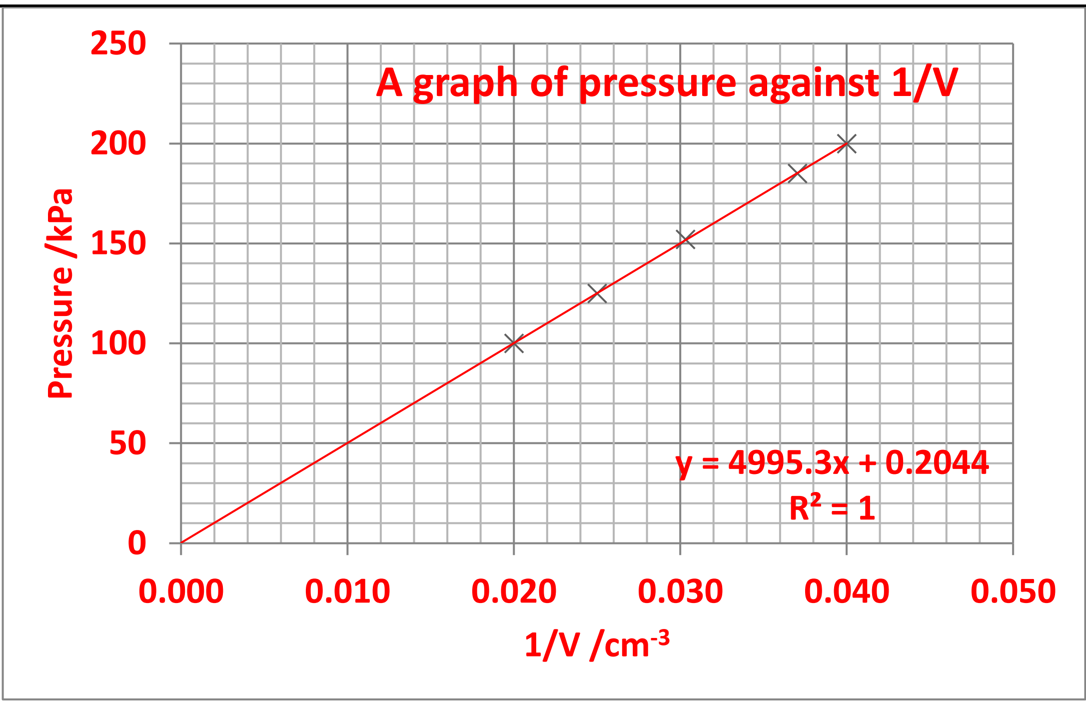
p	(kPa)	100	125	152	185	200
V	(cm^3)	50	40	33	27	25
1/V	(cm^{-3})	0·020	0·025	0·030	0·037	0·040

No.	CONTENT
	(a) (i) Using square-ruled paper, draw a graph of p against 1/V. You must start the scale on each axis from 0. (ii) Explain how the graph confirms that pressure is directly proportional to 1/volume.
	

(i)	Axes labelled with units Axes scaled linearly Data points accurately plotted with line of best fit	1 1 1	3	
(ii)	The line of best fit is a straight line which passes through the origin		1	
	$p_1V_1 = p_2V_2$ $125 \times 40 = p_2 \times 8 \cdot 0$ $p_2 = 630$ kPa	1 1 1	3	Accept 600, 625, 625·0 Accept any given data points or points selected from graph
	As volume decreases, the particles of gas will strike the piston of the syringe more often Since $P = \frac{F}{A}$, this results in an increased pressure	1 1	2	

No.	CONTENT

(i)	Using a clamp will prevent heat from the student's hand increasing the temperature of the gas in the syringe 1 If the temperature of the gas in the syringe is not constant, the experiment would not be valid 1	**2**	Or equivalent statements
(ii)	The suggestion is incorrect because the volume of air in the tubing is not being read from the scale on the syringe 1 A longer length of tubing would increase the (systematic) uncertainty in the experiment 1	**2**	Or equivalent statements



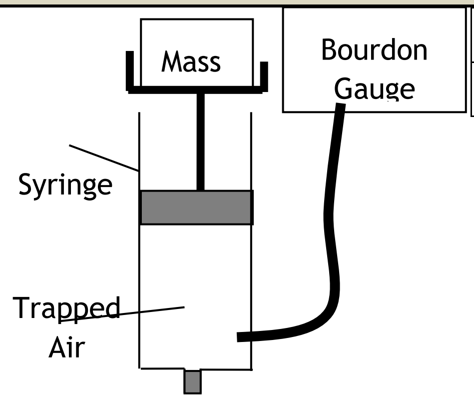
The graph is a straight line through the origin confirming that pressure is directly proportional to 1/volume.

16.9.4

In an experiment, a mass with a weight of 1N is placed on top of a syringe filled with trapped air. A Bourdon Gauge is used to measure the air pressure inside the syringe. This is then repeated for different masses. The results are given in the table.

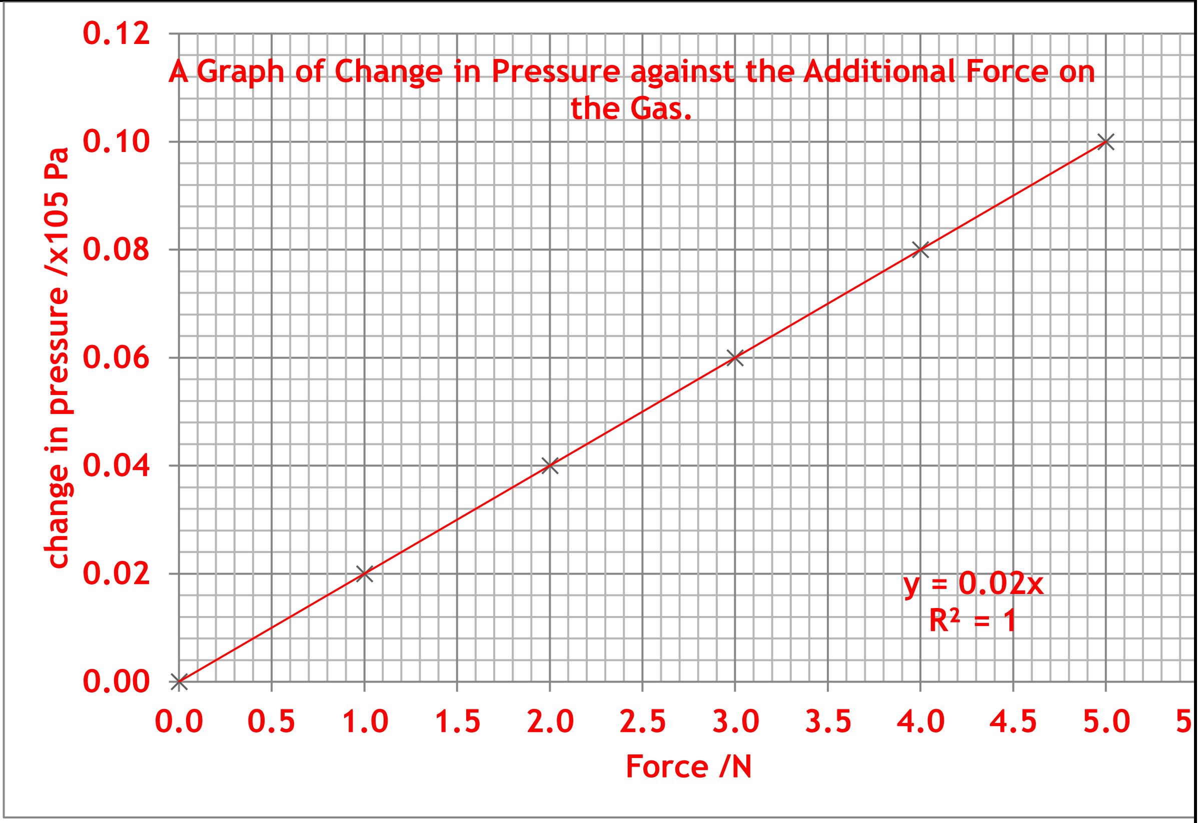
Force / N	*Pressure* / x 10^5 Pa
0	1.01
1	1.03
2	1.05
3	1.07

No.	CONTENT		
		4	1.09
		5	1.11

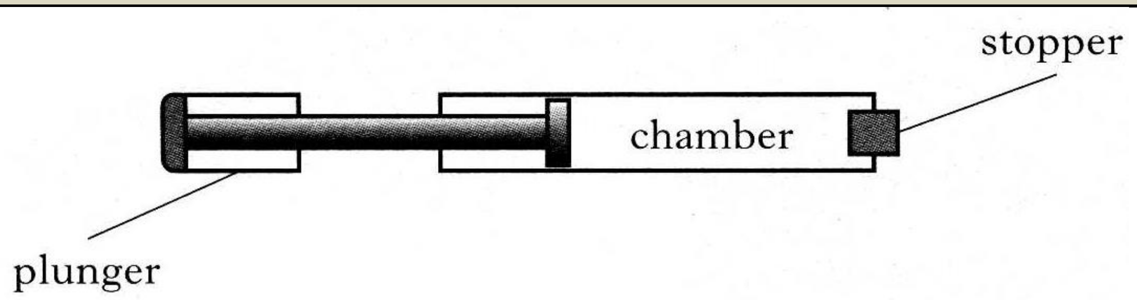


Use this data to construct a line graph of force against change in pressure, and use the gradient of the straight line to calculate the surface area of the syringe plunger inside the syringe.

Force / N	Pressure / x 10^5 Pa	Δ Pressure / x 10^5 Pa
0	1.01	0.00
1	1.03	0.02
2	1.05	0.04
3	1.07	0.06
4	1.09	0.08
5	1.11	0.10



16.9.5	The end of a bicycle pump is sealed with a stopper so that the air in the chamber is trapped.

No.	CONTENT
	 The plunger is now pushed in slowly causing the air in the chamber to be compressed. As a result of this the pressure of the trapped air increases. Assuming that the temperature remains constant, copy out the statements which correctly explain why the pressure increases. I The air molecules increase their average speed. **II The air molecules are colliding more often with the walls of the chamber.** III Each air molecule is striking the walls of the chamber with greater force. Statement I and III would occur if the temperature of the gas increased. Although the pressure increases the force of one air molecule on the wall remains constant at constant temperature.
16.9.6	A student is training to become a diver. (a) The student carries out an experiment to investigate the relationship between the pressure and volume of a fixed mass of gas using the apparatus shown. The pressure of the gas is recorded using a pressure sensor connected to a computer. The volume of the gas is also recorded. The student pushes the piston to alter the volume and a series of readings is taken. The temperature of the gas is constant during the experiment. The results are shown.

Pressure/kPa	100	105	110	115
Volume/cm3	20	19	18.2	17.4

(i) Using all the data, establish the relationship between the pressure and volume of the gas.

Pressure/kPa	100	105	110	115
Volume/cm3	20	19	18.2	17.4
pV (kPa cm^{-3})	2000	1995	2002	2001

You need to show the calculations pV

100 ×20=

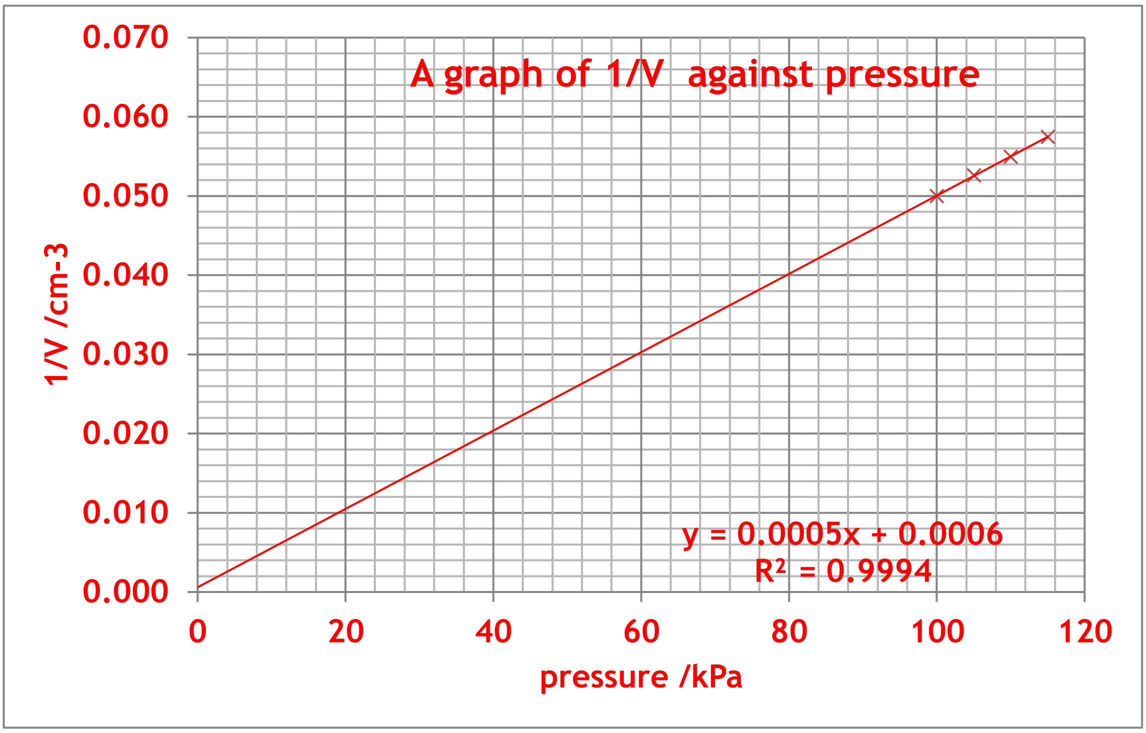
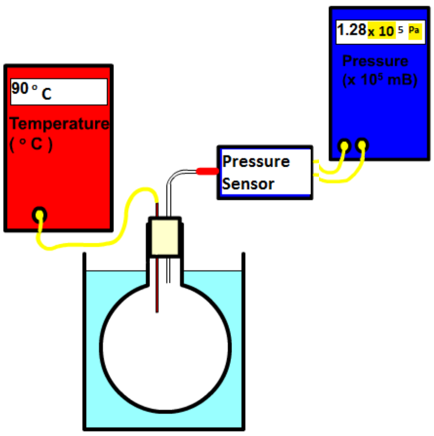
105×19

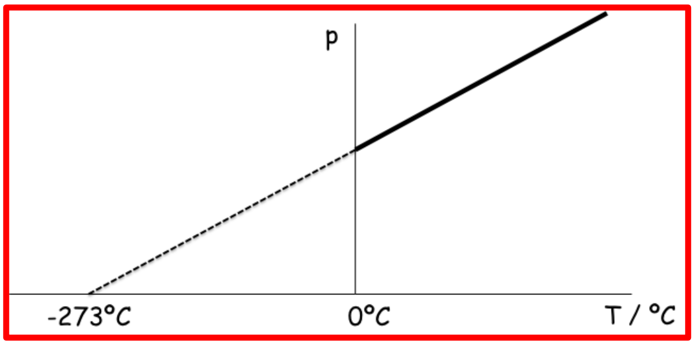
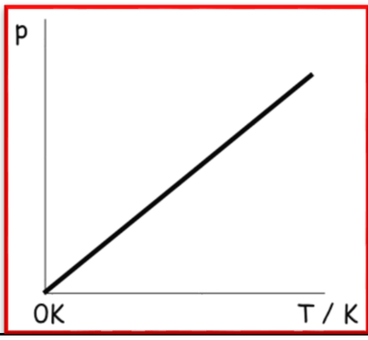
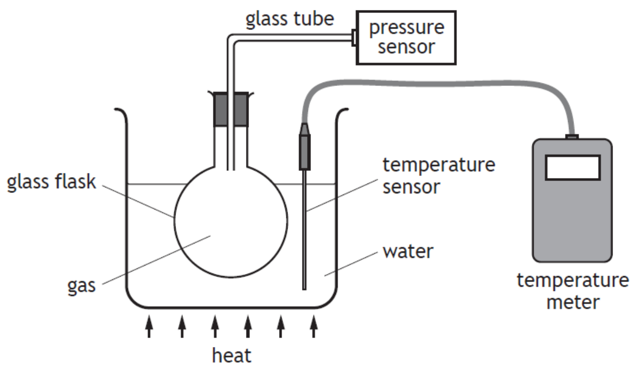
110 ×18.2

115×17.4

To one significant figure p × V = 2000= constant

Or you can plot a graph but this would take a lot longer so is not

No.	CONTENT
	recommended especially as you'd need to do the calculation first to show that a graph of p against 1/V is a straight line through the origin.  *The graph is a straight line and nearly passes through the origin showing that p is inversely proportional to V or p is directly proportional to 1/V* (ii) Use the kinetic model to explain the change in pressure as the volume of gas decreases. As the volume of the gas decreases the particles hit the walls of the container more often as there is a shorter distance between collisions. The force on the container increases and hence the pressure increases.
16.10	**I can describe an experiment to verify Gay-Lussac's Law (pressure and temperature)**
16.10.1	 Explain how the following equipment can be used to show the relationship between pressure and temperature. State the measurements required and how the variable will be altered. include any assumptions made. The round bottom flask contains a fixed mass of gas in a fixed volume. The water in the flask is heated gently and the temperature from the temperature recorded at the same time as a reading of pressure from the pressure sensor taken. The assumptions are that the gas is ideal, the volume remains constant, the tube to the pressure sensor is very short and that the temperature of all the gas is at the same temperature

No.	CONTENT
16.10.2	Discuss whether the thermometer should be placed in the round bottom flask or in the water. The SQA suggest that the thermometer should be placed inside the flask so that the temperature of the gas is measured. Some experiments have suggested it works better if the temperature of the water is taken. For your purposes I would stick with the SQA, although it assumes that the water is not heated up too rapidly.
16.10.3	Sketch a graph of the expected results of pressure against temperature on the degrees Celsius scale. ***You are not required to extrapolate the graph back to -273 ℃*** 
16.10.4	Sketch a graph of the expected results of pressure against temperature on the kelvin scale. 
16.10.5	SQA N5 2018 Q9 A student sets up an experiment to investigate the relationship between the pressure and temperature of a fixed mass of gas as shown.  (a) The student heats the water and records the following readings of pressure and temperature. **Pressure (kPa)**: 101, 107, 116, 122 **Temperature (K)**: 293, 313, 333, 353 (i) Using all the data, establish the relationship between the pressure and the temperature of the gas. (ii) Predict the pressure reading which would be obtained if the student was to cool the gas to 253 K. (b) State one way in which the set-up of the experiment could be improved to give more reliable results.

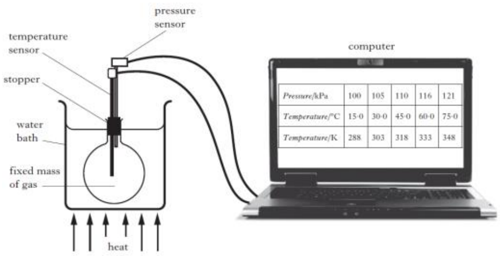
No.	CONTENT		
	All four substitutions for $\frac{p}{T}$ OR $\frac{T}{p}$ (1) All values calculated correctly (1) For $\frac{p}{T}$: $\frac{101\times10^3}{293} = 345$ $\frac{107\times10^3}{313} = 342$ $\frac{116\times10^3}{333} = 348$ $\frac{122\times10^3}{353} = 346$ For $\frac{T}{p}$: $\frac{293}{101\times10^3} = 0{\cdot}00290$ $\frac{313}{107\times10^3} = 0{\cdot}00293$ $\frac{333}{116\times10^3} = 0{\cdot}00287$ $\frac{353}{122\times10^3} = 0{\cdot}00289$ Statement of: $\frac{p}{T} = constant$ OR $\frac{T}{p} = constant$ OR $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ OR p is (directly) proportional to T (in kelvin) (1)	3	If only 1 or 0 sets of data used (0) for entire question Substitutions may be implied by all four calculated values. For the second mark, values must be calculated correctly for all substitutions shown by the candidate (minimum of using at least two sets of data). Accept 2-5 sig figs in all calculated values. Conversion from kPa to Pa not required. Mark for $\frac{p}{T} = \text{constant}$ can only be accessed if the candidate has completed calculations using a minimum of two sets of data, however the relationship must be supported by all the candidate's calculated values. Do not accept $\frac{pV}{T} = constant$ **Graphical method:** Must be on graph paper for any marks to be awarded suitable scales, labels and units (1) all points plotted accurately to ±half a division and line of best fit (1) relationship stated (1)

No.	CONTENT

		Alternative method: If candidate uses $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ to verify values of pressures or temperatures in the table then they must make it clear that the calculated value is approximately the same as the value in the table for any marks to be awarded. Thereafter: All four sets of data linked (minimum of three calculations) (1) All calculations correct (1) Relationship stated and supported (1)

(The increase in temperature) increases the kinetic energy of the gas particles/the particles move faster. **(1)** The particles hit the container/walls more frequently. **(1)** The particles hit the container/walls with greater force. **(1)**	**3**	Independent marks Accept: 'atoms'/'molecules' in place of 'particles' Do not accept: 'particles hit the container/walls more' alone
Any single value between 83 kPa and 89 kPa inclusive	**1**	Unit must be stated Excessive sig figs should be ignored.
Have more of the flask under the water, **(1)** so that the gas is at the same temperature/evenly heated **(1)** **OR** Reduce the length/diameter/volume of the connecting tube **(1)** so that the gas is at the same temperature/evenly heated **(1)**	**2**	Accept: Place the temperature sensor in the flask (1) So that the temperature of the gas is being measured (1) Accept: 'so that all the gas is being heated' Do not accept: 'repeat measurements' - it is an improvement to the set up that is required

16.10.6



A student carries out an experiment to investigate the relationship between the pressure and temperature of a fixed mass of gas. The apparatus used is shown.

The pressure and temperature of the gas are recorded using sensors connected to a computer. The gas is heated slowly in the water bath and a series of readings is taken.

The volume of the gas remains constant during the experiment.

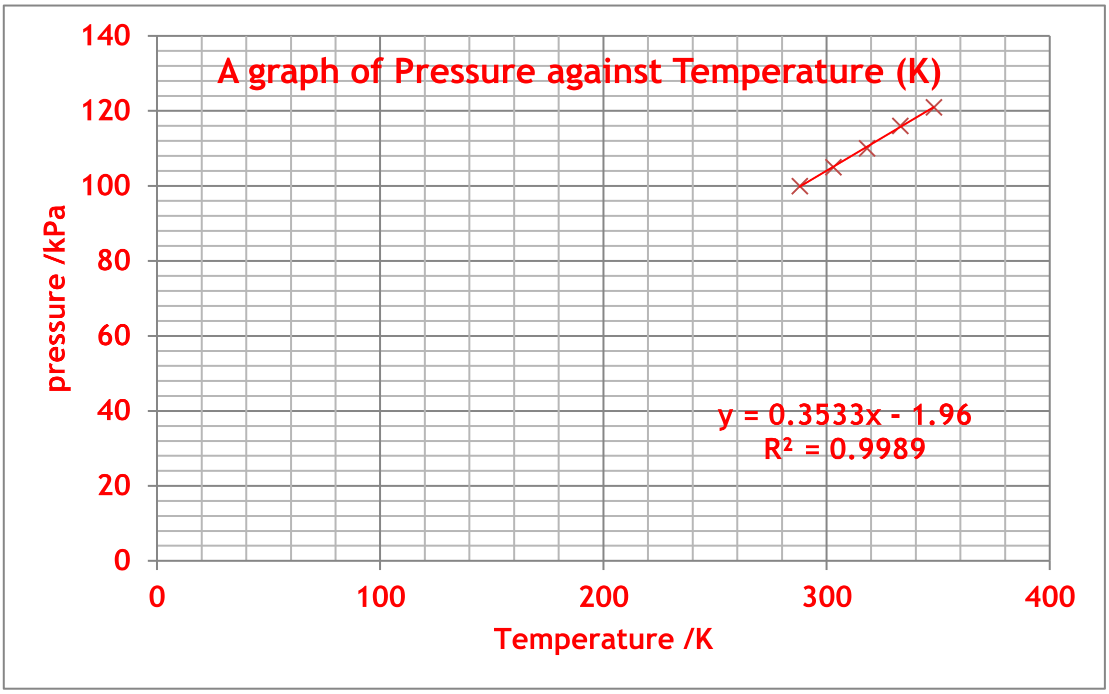
No.	CONTENT
	The results are shown.

Pressure/kPa	100	105	110	116	121
Temperature/°C	15·0	30·0	45·0	60·0	75·0
Temperature/K	288	303	318	333	348

(a) Using all the relevant data, establish the relationship between the pressure and the temperature of the gas.

(b) Use the kinetic model to explain the change in pressure as the temperature of the gas increases.

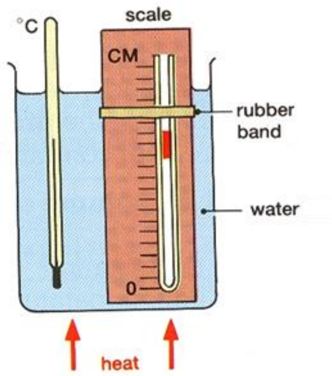
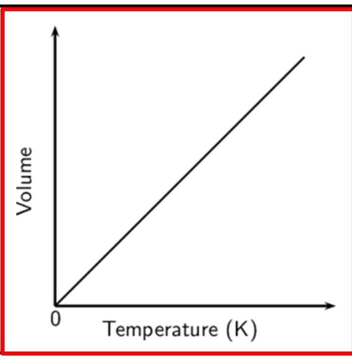
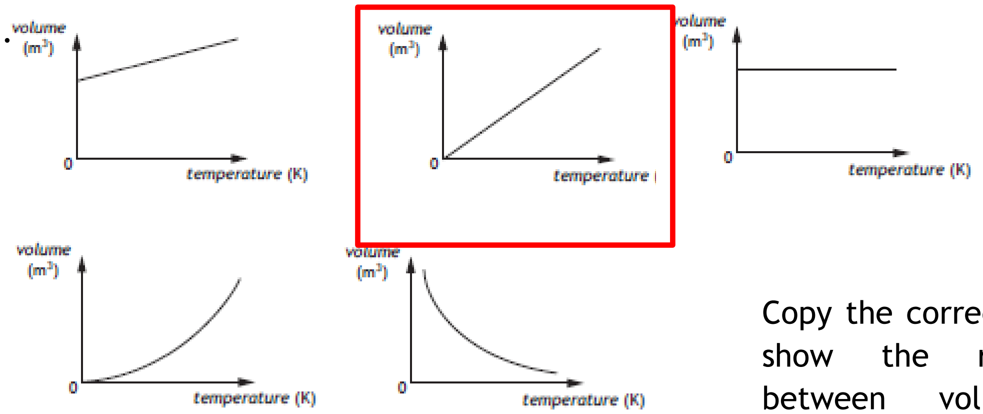
(c) Explain why the level of water in the water bath should be above the bottom of the stopper.



P/T= constant	=100/288	0.347222
	=105/303	0.346535
	=110/318	0.345912
	=116/333	0.348348
	=121/348	0.347701

Pressure/kPa	100	105	110	116	121
Temperature/°C	15	30	45	60	75
Temperature/K	288	303	318	333	348
p/ T(k)	0.347222	0.346535	0.345912	0.348348	0.347701

As P/T= constant= 0.35 then Pressure is directly proportional to Temperature in Kelvin

No.	CONTENT
16.11	**I can describe an experiment to verify Charles' Law (volume and temperature)**
16.11.1	 Explain how the following equipment can be used to show the relationship between pressure and temperature. State the measurements required and how the variable will be altered. Include any assumptions made.
16.11.2	A student is investigating the relationship between the volume and the kelvin temperature of a fixed mass of gas at constant pressure. Sketch a graph to shows this relationship. 
16.11.3	Explain why the set up in 16.11.1 requires the thin tube to be open at one end. So that the pressure can remain constant (and equal to the air pressure).
16.11.4	 Copy the correct graph to show the relationship between volume and temperature. NB K missing but all others K!
16.11.5	State what must be kept constant to allow a relationship between volume of a gas and its temperature. Mass of the gas and its pressure